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(54) ELECTROPHORETIC DISPLAY EMPLOYING GREY SCALE CAPABILITY UTILIZING AREA MODULATION

ELEKTROPHORETISCHE ANZEIGETAFEL UNTER VERWENDUNG VON GRAUSTUFENFÄHIGKEIT MIT FLÄCHENMODULATION

PANNEAU D'AFFICHAGE PAR ELECTROPHORESE A CAPACITE D'ECHELLE DE GRIS UTILISANT LA MODULATION DE ZONES

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- **PATENT ABSTRACTS OF JAPAN, vol. 13, no. 112 (P-844) 17 March 1989; & JP-A-63 287 828**

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formation which transforms each colour area of an original image into a corresponding area of monochromation image having a particular pattern of light and dark cots corresponding to and representing the original colour of the area. This does not however, allow the user to select grey scale according to the user's preference in order to highlight an area, or to underline an area, or to provide grey scale capability in a display, strictly according to the user's requirements and independently of the data in the display.

It is therefore an object of the present invention to provide a new or improved electrophoretic display having grey scale capability.

It is a further object of the present invention to provide an electrophoretic display apparatus which has grey scale capability and which operates to modulate the area about each character or the area within each character on a display.

According to one aspect of the invention we provide apparatus for providing grey scale capability for an electrophoretic information display (EPID), wherein said electrophoretic display is an X-Y addressable display with each X-Y coordinate indicative of a given column and row intersection, with each X-Y coordinate defining a pixel, which pixel when energized provides a different intensity display as compared to a non-energized pixel comprising, characterized in that means are coupled to said display for impressing upon said display a plurality of predetermined digital patterns that are independent of data or an image written on said display to cause said pixels in said display to be energized with respect to other pixels in said display according to a selected one of such patterns, said energized pixels being of same intensity as those pixels of an image on said display and each of said predetermined digital patterns being distinct and arranged in repetitive configurations that produce different grey scale levels, whereby the area about said image is effectively modulated according to said pattern to vary the contrast of said image with respect to the display background.

Thus grey scale operation at different shades of grey can be provided on the electrophoretic display by means of area modulation. Area modulation can be used to shade either the foreground, the background or both the foreground and the background. Such electrophoretic displays, as other displays, portray information by writing in two different colours or shades of the same colour. These, of course, can be referred to as black or white, although many other colour combinations are available as indicated above. Thus, in an electrophoretic display, the normal background colour is the colour of the pigment used in the display and the written characters and graphics are generated by removing pigment from th appropriate ar as. In the revers or inverse video mode the pigment is r moved from the background while pigment is retained in the areas of the characters or graphics. This is th same difference, for example, b tween a n gative and positive in photography.

By performing area modulation by writing a pattern of either black or white pixels in either the background, foreground or both, permits generation of shades of grey. It is also understood that area modulation can be used with any relatively high resolution display to in fact provide a grey scale capability for the display.

In accordance with a second aspect of the invention we provide a method of providing grey scale capability for electrophoretic information display (EPID) of the type employing pixel selection, characterised by the steps of:

storing a plurality of digital patterns with each said digital pattern being distinct and arranged in repetitive configurations that produce different grey scale levels, said stored patterns, when applied to an electrophoretic display, to cause said pixels in said display to be energized with respect to other pixels in said display in accordance with a desired grey scale level, and with each said energized pixel being of same intensity as those pixels of an image on said display, and selecting a stored pattern for application to said display by means independent of data or an image written on said display, to cause said display to exhibit said grey scale level whereby the area about said image is effectively modulated according to said pattern to vary the contrast of said image with respect to the display background.

Figure 1 is a side plan view of an electrophoretic display (EPID) employed in this invention;
Figure 2 is a perspective plan view of an electrophoretic display panel showing a given number of grid and cathode lines;
Figure 3 is a graph depicting a character block displayed on a conventional black and white display;
Figure 4 depicts a character displayed with a predetermined area modulated background pattern;
Figure 5 shows still another area modulated pattern;
Figure 6 is a diagram showing still another pattern;
Figure 7 is a diagram showing still another pattern;
Figure 8 is a diagram showing an alternate pattern;
Figure 9 is a diagram showing still another alternate pattern;
Figure 10 is a diagram of a character block showing an alternate background pattern;
Figure 11 is a diagram of a character block showing an alternate background pattern;
Figure 12 is a schematic diagram partially in block form showing a circuit for deriving a grey scale value for an electrophoretic display employing area modulation;
Figure 13 shows an OR gate employed in this invention;
Figure 14 shown an AND gate employed in this invention;
Fig. 15 shows a logic circuit for providing grey background or characters; and
Fig. 16 shows a logic circuit for providing the character and background features.

Referring to Figure 4, there is again shown the character E within the character block 32 having a 50 percent grey background. Essentially, the character E is the same as shown in Figure 3 but the background consists of alternate pixels of black and white as can be seen, for example, from Figure 4. Across the top line 40, the 16 pixels are indicative of white, black, white, black and so on. On line 41, the pattern is black, white, black, white and so on. This pattern then continues to alternate down and across the display so that it alternates as to the 16 horizontal pixels and the 24 vertical pixels. The background appears grey when the image is viewed at a distance where the individual pels are unresolved. Because of this property, the number of grey shades obtainable via area modulation is again a function of the display's resolution, the size of the character and the viewing distance. As one can ascertain, the background area is modulated accordingly to produce patterns which have grey scale capability due to the nature of the modulation technique.

Referring to Figure 5, there is shown the character block which now possesses an area modulated background which is 93.25 percent black. This is obtained by formulating each horizontal line within the character block, all within the display area by means of a particular Hex code. As seen in Figure 5, line 50 is indicative of the Hex code EE where black is equal to binary one and white is equal to binary 0. Based on the display format shown in Figure 5, in order to obtain a background which his 93.25 percent black, one modulates the display lines as follows. The first line 50 as seen is BBBWBBBWBB-BWBBBW (Hex EE). The next three lines 51, 52, and 53 are all black or all B (Hex FF). The fourth line is BWBBBWBBBWBBBWBB (Hex BB). At the right of each line, there is shown the Hex code for the line. As one can see from the Hex code notation, it is a repetitive pattern which specifies the display background as in Figure 5 to obtain a background which is 93.25 percent black. The line pattern for the display of Figure 5 is HEX, EE, FF, FF, FF, BB, FF, FF, FF and repeats for the 24 lines.

Referring to Figure 6, there is shown an area modulated background or character block which is 87.5 percent black. The Hex line values are shown at the right hand side to denote the repetitive pattern. As one can see from Figure 6, line 61 is BWBBBWBBBWBBBWBB which is Hex code BB. Line 62 is all black which is Hex FF. Line 63 is BBBWBBBWBBBWBBBW which is hex code EE. Line 64 is all black as Hex code FF.

Referring to Figure 7, there is shown an area modulated background pattern which is 62.5 percent black. The Hex code is shown at the right and is a relatively simple repeating code with the first line 70 being WBB-BWBBBWBBBWBBB or Hex 77. Line 71 is BBWBB-BWBBBWBBBWB which is H x DD and then th pattern repeats as Hex 77, DD, 77, DD, 77, DD...etc.

Ref rring to Figur 8, there is shown a pattern which is 50 percent black and has a simple repeat as line 80 is BWBWBWBW... etc. Line 81 is WBWBWB etc. which respectively denotes the Hex code of AA and 55, which code repeats for the 24 lines.

Referring to Figure 9, there is shown an area modulated display or character block which is 37 5 percent black. The Hex code is shown on the right as line 90 is Hex code AA as for example indicative of line 80 of Figure 8, while line 91 is Hex code 44 which is WBWWW-BWWWBWWWBWW. Line 92 is the same as line 90 (AA) while line 93 is Hex code 11 or WWWBWWWBW-WWBWWWB. The code then alternates as seen in Figure 9.

Referring to Figure 10, it depicts a character block or display having 25 percent black background. The Hex code is shown on the right hand side for each line.

Referring to Figure 11, it shows a display or character block, the Hex code again at the right exhibiting a 12.4 percent black background. As one can ascertain, the above-noted figures essentially depict six different patterns which six patterns will yield seven different shades of grey when viewed at normal viewing distance on a 200 x 200 line per inch electrophoretic display. These patterns coupled with black and white yield a system with nine shades of grey. However, in practice, a background of 12.5 percent black can be omitted as exhibiting a small difference from white. The patterns as one can easily ascertain, which are distinct are shown in Figures 5-11. These figures represent various patterns which yield different shades of grey when viewed at a normal viewing distance on a 200 x 200 line per inch electrophoretic display.

The system as shown with a 200 line resolution including black and white can produce eight different effective shades of grey. The patterns used to achieve area modulation in a character type or graphics type display when the graphics are formed using special characters must be a factor of the character block. For example, in a display using a character block which is 16 pixels wide and 24 pixels high, the width of the area modulated pattern must be a factor (divisor) of 24 and the height of the pattern must be a factor (divisor) of 16. The figures shown in the above-noted application, as indicated for example in Figure 3, are patterns which are designed for a 16 x 24 pel character block. The figures show patterns which have increasingly more white (less grey), however, the actual grey shade that the human eye perceives is dependent upon many factors including display type, ambient lighting, color and other factors. It may be necessary to have unequal increments in the percentages of black and white in successive patterns to generate scales which are subjectively more and more grey.

There are many techniques as one can imagine for accommodating area modulation which can be implem nted simply by using registers and appropriate gating modules.

Displays using shades of grey require that an attribute which describes the image foreground and back-

whereby there is a data receiver 57 which is capable of receiving data from a typical telephone line or other transmission medium. This data receiver may be a conventional modem. The output of the data receiver is coupled to an analog to digital converter 56 for transforming the analog signals at the input to digital signals at the output of the analog-to-digital converter 56. The analog-to-digital converter 56 is associated with a digital signal pixel generator 58 which operates in conjunction with the master decoder 50 to allow one to perform area modulation at various pixel sites as desired. The output of the decoder 50 is also coupled to the X address register and the Y address register 40 and 41. The area modulation memory 51 is shown coupled to the decoder 50, but can of course be part of the microprocessor memory where a certain section will be reserved for the different area modulation background codes. As shown in Figure 12, the module designated as grey scale select 60 is coupled to the area modulation memory 51. The module 60 decodes the particular grey scale request which data may be forwarded to the module 60 by means of the character generator 52 or by means of the decoder 50. In this manner, the system by decoding the transmitted data would automatically determine what grey scale is to be utilized for a particular display. This can be automatically done by means of suitable decoders or can be implemented at the preference of the user. As shown in Figure 12, the character generator 52 is also coupled to the grey scale select module 60 and a user while viewing an image can go ahead and select the grey scale value desired and according to the preference of the user. As one can immediately ascertain from Figure 12, area modulation can be simply implemented. One technique of implementing the area modulation is that the decoder or microprocessor 50 combines the area modulation code as stored in the area modulation memory with the data code. For example, if black is equal to 1 and white is equal to 0 then an "AND" or "OR" function can be used. In the OR function, whenever a pixel does not contain data, the pixel would receive the exact binary digit indicative of the background code. Where a pixel does contain data, the output will be a 1 if the data is a 1. If the data is 0 and the background is a 1, the output would also be a 1 according to the area modulation pattern as stored. Thus, the OR function provides a full black or dark character with the selected grey background as stored in the area modulation memory 51. Thus, the patterns depicted in the above-noted Figures 5-11 can be combined with he data pattern, to provide AND and OR functions or both as will be further explained. To present the characters or graphics with a desired shade of grey, the procedures described above can be used except the OR is replaced with an AND function.

In this manner, both the data and the area modulation bit must be the same in order to produce a black spot at the output. If they are not the same then the color of the pixel remains white. As one can see, one will produce a character having a different grey scale which is presented on an all white or in the case of a negative application on an all black background. In an inverse video mode the function used to obtain a grey background is the AND function occurring between the pixel data and the stored area modulation pattern. To make the characters grey in an inverse video mode, one would employ the OR function between a grey background pattern and a pixel data pattern. As indicated above and briefly described, either the characters (foreground) or the background of a display can have grey scale. Both these options and the no grey scale option can be readily generated by means of simple combinatorial circuits.

Referring to Figure 13, no grey scale requires no gating. The grey background is accomplished by OR gating the character data bit stream with the grey scale pattern bit stream as shown in Figure 13. Thus, as indicated in Figure 13, there is shown an OR gate 70 with one input designated as CHAR representative of the character bit stream and the other input designated as the grey bit steam.

As one can ascertain, the grey bit stream would be that stream or data which has been defined in conjunction with Figures 5-11.

Referring to Figure 14, there is shown an AND gate 71 having one input designated as by CHAR and indicative of the character bit stream and the other input receiving the grey bit stream as again shown in the above-noted figures. The output of the AND gate 71 is directed to the display or to the display drivers as is the output of gate 70. The grey characters are generated by the AND gate 71 which will produce grey character on a constant background. Typically, the color of each character can be described by a number of additional bits which are designated as attribute bits or an attribute byte. This set of bits or byte are normally required for each character to be displayed. The number of bytes of attribute data could be reduced by means of many different schemes which are not pertinent to this aspect of the invention. For example, an attribute byte with the following bit interpretations can be employed for generating grey scale displays.

00000000 no grey scale (black characters on white.
00000001 grey background with black characters.
00000010 grey characters with white background.

It is noted that in the above examples only 2 bits, as for example, the first and second bits are needed to generated the grey display. The other bits typically are used to specify the shade of grey desired. For simplicity, assume the desired grey shade has been selected and will be used when grey is required. With these assumptions and the example attribute code specified above, only a simple logic circuit is required to generate the required bit stream.

Referring to Figure 15, there is shown a logic circuit capable of generating an output signal for the display

means coupled to said memory means for selecting any desired one of said stored digital patterns for application to said display.

7. The apparatus according to Claim 6. wherein said electrophoretic display is a high resolution display.

8. A method of providing grey scale capability for an electrophoretic information display (EPID) of the type employing pixel selection, characterised by the steps of:

storing a plurality of digital patterns with each said digital pattern being distinct and arranged in repetitive configurations that produce different grey scale levels, said stored patterns, when applied to an electrophoretic display, to cause said pixels in said display to be energized with respect to other pixels in said display in accordance with a desired grey scale level and with each said energized pixel being of same intensity as those pixels of an image on said display and
selecting a stored pattern for application to said display, by means independent of data or an image written on said display, to cause said display to exhibit said grey scale level whereby the area about said image is effectively modulated according to said pattern to vary the contrast of said image with respect to the display background.

9. The method according to Claim 8, characterised in that said energized pixels are background pixels to provide a grey background with respect to a different intensity character.

10. The method according to Claim 8, characterised in that said energized pixels are character pixels to provide a grey character with respect to a different intensity background.

11. The method according to Claim 10, characterised in that said different intensity background is indicative of white.

12. The method according to Claim 10, characterised in that said stored digital patterns are at least six patterns indicative of six different grey scale levels.

13. The method according to Claim 10, characterised in that there is included the step of "OR"ing said selected pattern with a character pattern prior to applying said character pattern to said display to display a given intensity character on a background of said selected grey scale level.

14. The method according to Claim 10, characterised in that there is included the step of "AND"ing said selected pattern with a character pattern prior to applying said character pattern to said display to display a given intensity background having a character impressed thereon of said selected grey scale level.

Patentansprüche

1. Vorrichtung zur Schaffung eines Graustufungsvermögens für eine elektrophoretische Informationsanzeige (EPID), wobei besagte elektrophoretische Anzeige eine X-Y-adressierbare Anzeige ist, in der jede X-Y-Koordinate einen gegebenen Schnittpunkt zwischen Spalten und Zeilen bezeichnet und jede X-Y-Koordinate ein Bildelement definiert, das bei Erregung eine Anzeige anderer Intensität ergibt als ein nichterregtes Bildelement, dadurch gekennzeichnet, daß

an besagte Anzeige Mittel zum Aufdrücken von mehreren vorgegebenen Digitalstrukturen auf besagte Anzeige angekoppelt sind, die unabhängig von den Daten oder einem auf besagte Anzeige geschriebenen Bild sind und die Erregung besagter Bildelemente in besagter Anzeige in bezug auf andere Bildelemente in besagter Anzeige gemäß einer gewählten derartigen Struktur veranlassen, wobei besagte erregte Bildelemente die gleiche Intensität haben wie jene Bildelemente eines Bildes auf besagter Anzeige und jede besagte vorgegebene Digitalstruktur verschiedenartig und in sich wiederholenden Konfigurationen angeordnet ist, die unterschiedliche Graustufen ergeben, und wobei die Fläche um besagtes Bild zur Variierung des Kontrastes des besagten Bildes in bezug auf den Anzeigehintergrund gemäß besagter Struktur wirksam moduliert wird.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß besagtes Bildelement bei Erregung eine dunkle Intensität im Vergleich zu einer helleren Intensität im nicht-erregten Zustand zur Anzeige bringt, wobei besagte dunklere Intensität einer Schwarzstufe und besagte hellere Intensität einer Weißstufe entspricht.

3. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß besagte Digitalstruktur mit Hilfe von UND-Schaltungsmitteln so auf besagte Anzeige aufgedrückt ist, daß die auf besagte Anzeige geschriebenen Zeichen besagte Graustufe in bezug auf den Hintergrund besagter Anzeige aufweisen.

4. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß besagt Digitalstruktur mit Hilfe von ODER-Schaltungsmitteln so auf b sagte Anzeige aufgedrückt ist, daß besagter Hintergrund besagte

FIG-8

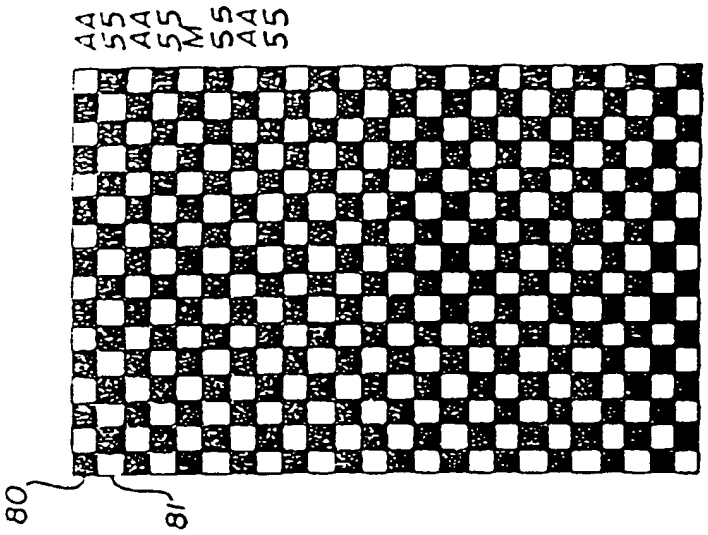


FIG-7

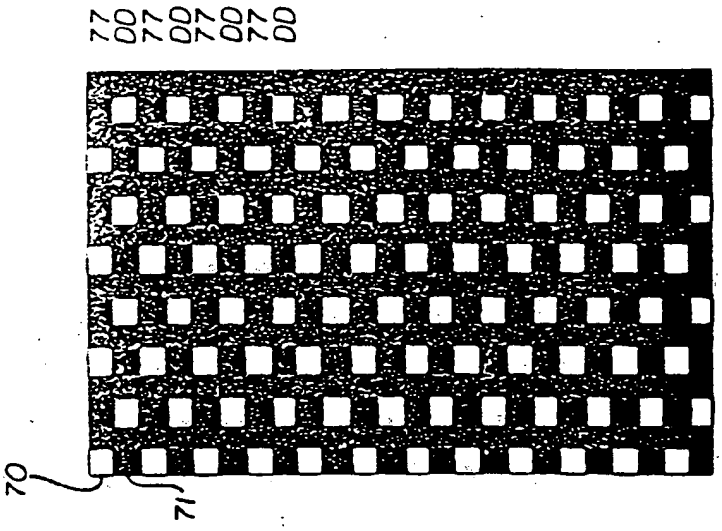
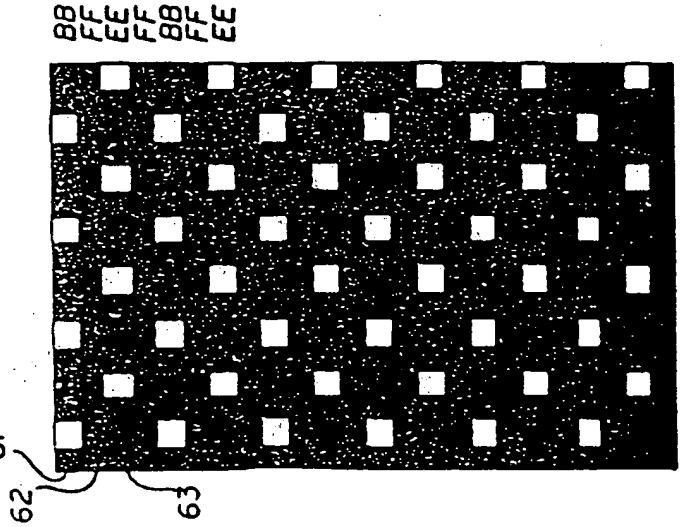


FIG-6



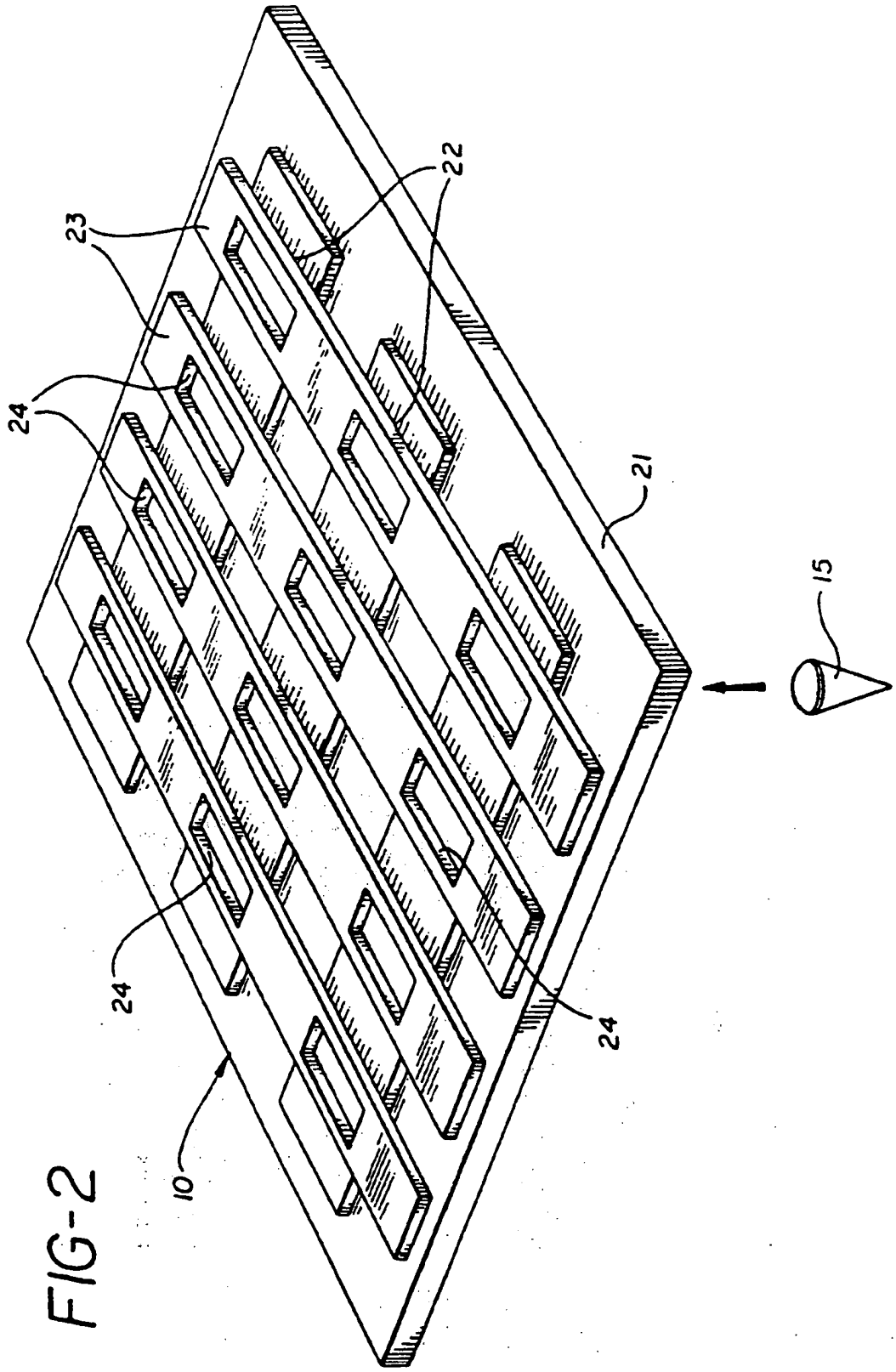


FIG-2

rier ladite image par rapport à l'arrière-plan de l'affichage.

2. L'appareil suivant la Revendication 1, caractérisé en ce que ledit pixel, quand il est excité, affiche une intensité foncée par rapport à une intensité plus claire quand il n'est pas excité, ladite intensité plus foncée correspondant à un niveau de noir et ladite intensité plus claire correspondant à un niveau de blanc.

3. L'appareil suivant la Revendication 1, caractérisé en ce que ledit motif numérique est appliqué sur ledit affichage au moyen de moyens logiques ET pour que les caractères, tels qu'ils sont écrits sur ledit affichage, présentent ledit niveau de l'échelle des gris par rapport à l'arrière-plan dudit affichage.

4. L'appareil suivant la Revendication 1, caractérisé en ce que ledit motif numérique est appliqué sur ledit affichage au moyen de moyens logiques OU pour que ledit arrière-plan présente ledit niveau de l'échelle des gris par rapport aux caractères sur ledit affichage.

5. L'appareil suivant la Revendication 1, caractérisé en ce que ledit moyen comprend de plus des moyens logiques qui fonctionnent pour que les caractères écrits dans ledit affichage et ledit arrière-plan dudit affichage soient excités selon ledit motif numérique et conformément audit niveau souhaité de l'échelle des gris.

6. L'appareil suivant la Revendication 1, caractérisé en incluant des moyens de mémoire pour y stocker une pluralité de motifs numériques, chacun étant indicatif de différents niveaux souhaités de l'échelle des gris, et

des moyens couplés auxdits moyens de mémoire pour sélectionner le motif souhaité parmi lesdits motifs numériques stockés pour une application sur ledit affichage.

7. L'appareil suivant la Revendication 6, dans lequel ledit affichage électrophorétique est un affichage de haute résolution.

8. Une méthode pour procurer une capacité de reproduction des gris pour un affichage d'informations électrophorétique (EPID) du type qui emploie la sélection des pixels, caractérisées par les étapes :

de stockage d'une pluralité de motifs numériques, chaque motif numérique étant distinct et disposé en configurations répétitives qui produisent différents niv aux de l'échelle des gris, lesdits motifs stockés, lors de leur application sur un affichage électrophorétique, causant l'excitation desdits pixels dans ledit affichage par rapport aux autres pixels dans ledit affichage conformément au niveau souhaité de l'échelle des gris, et chaque pixel excité étant de la même intensité que les pixels d'une image sur ledit affichage, et

de sélection d'un motif stocké pour application sur ledit affichage par un moyen indépendant des données ou d'une image écrite sur ledit affichage, pour que ledit affichage présente le niveau d'échelle des gris par quoi la zone de ladite image est efficacement modulée selon ledit motif pour varier le contraste de ladite image par rapport à l'arrière-plan de l'affichage.

9. La méthode suivant la Revendication 8, caractérisée en ce que lesdits pixels excités sont des pixels d'arrière-plan pour procurer un arrière-plan gris par rapport à un caractère d'une intensité différente.

10. La méthode suivant la Revendication 8, caractérisée en ce que lesdits pixels excités sont des pixels de caractère pour procurer un caractère gris par rapport à un arrière-plan d'une intensité différente.

11. La méthode suivant la Revendication 10, caractérisée en ce que ledit arrière-plan d'une intensité différente est indicatif de blanc.

12. La méthode suivant la Revendication 10, caractérisée en ce que lesdits motifs numériques stockés sont au moins six motifs indicatifs de six niveaux différents de l'échelle des gris.

13. La méthode suivant la Revendication 10, caractérisée en ce qu'il y a d'inclus l'étape d'opération "OU" sur ledit motif sélectionné avec un motif de caractère avant d'appliquer ledit motif de caractère sur ledit affichage pour afficher un caractère d'une intensité donnée sur un fond dudit niveau sélectionné de l'échelle des gris.

14. La méthode suivant la Revendication 10, caractérisée en ce qu'il y a d'inclus l'étape d'opération "ET" sur ledit motif sélectionné avec un motif de caractère avant d'appliquer ledit motif de caractère sur ledit affichage pour afficher un arrière plan d'une intensité donnée ayant un caractère appliqué dessus dudit niveau sélectionné de l'échelle des gris.

FIG-12

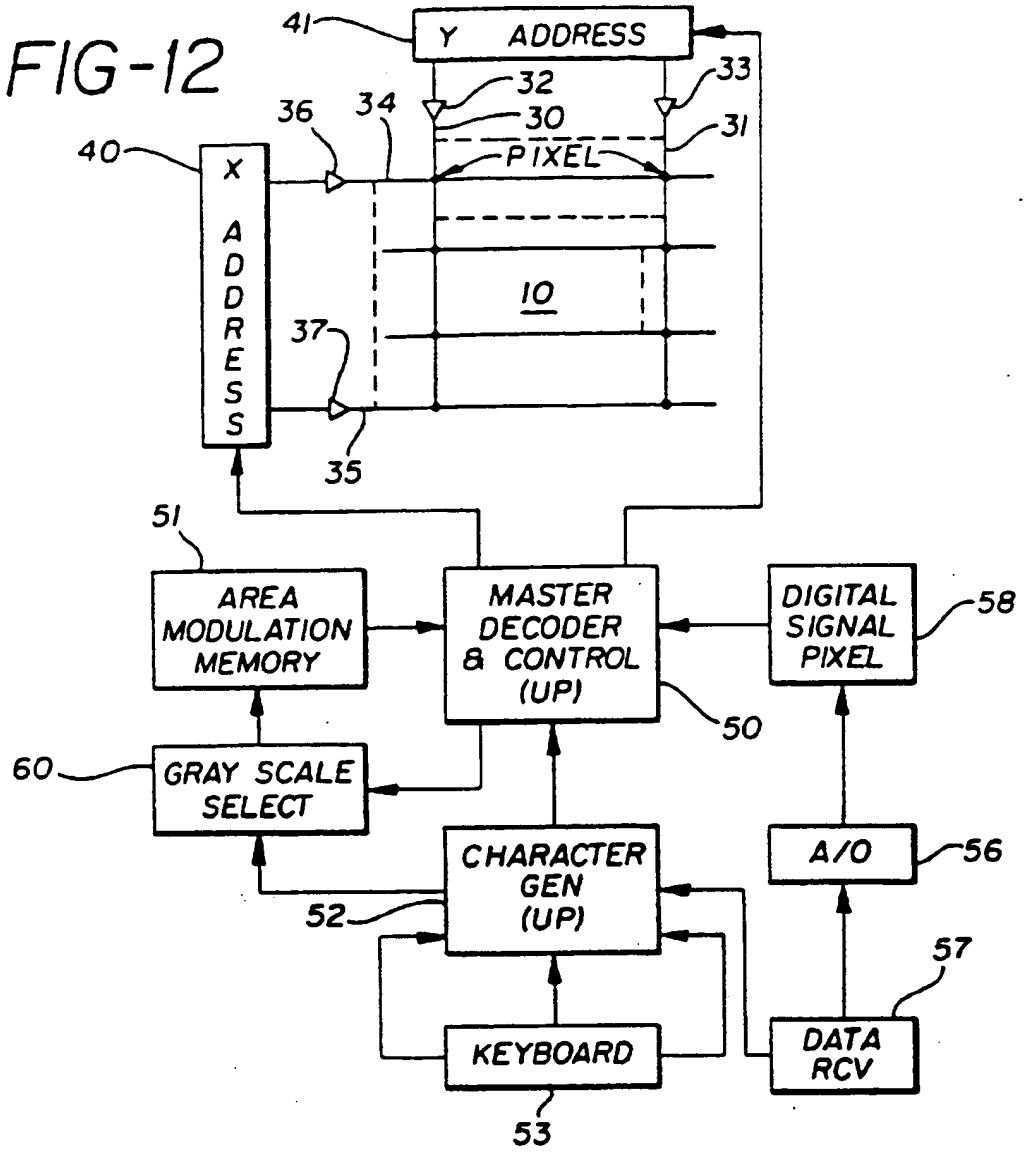


FIG-13

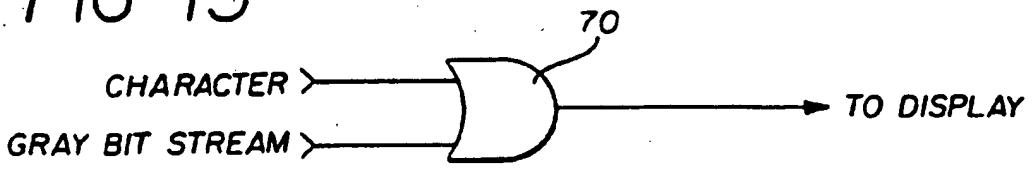


FIG-14

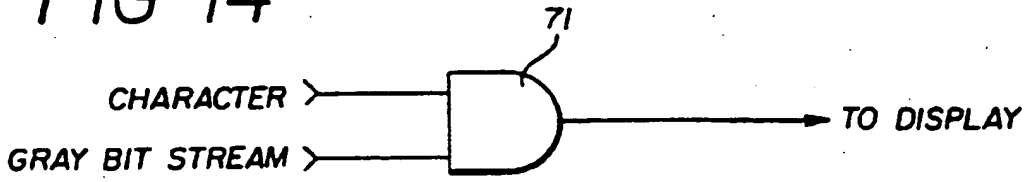
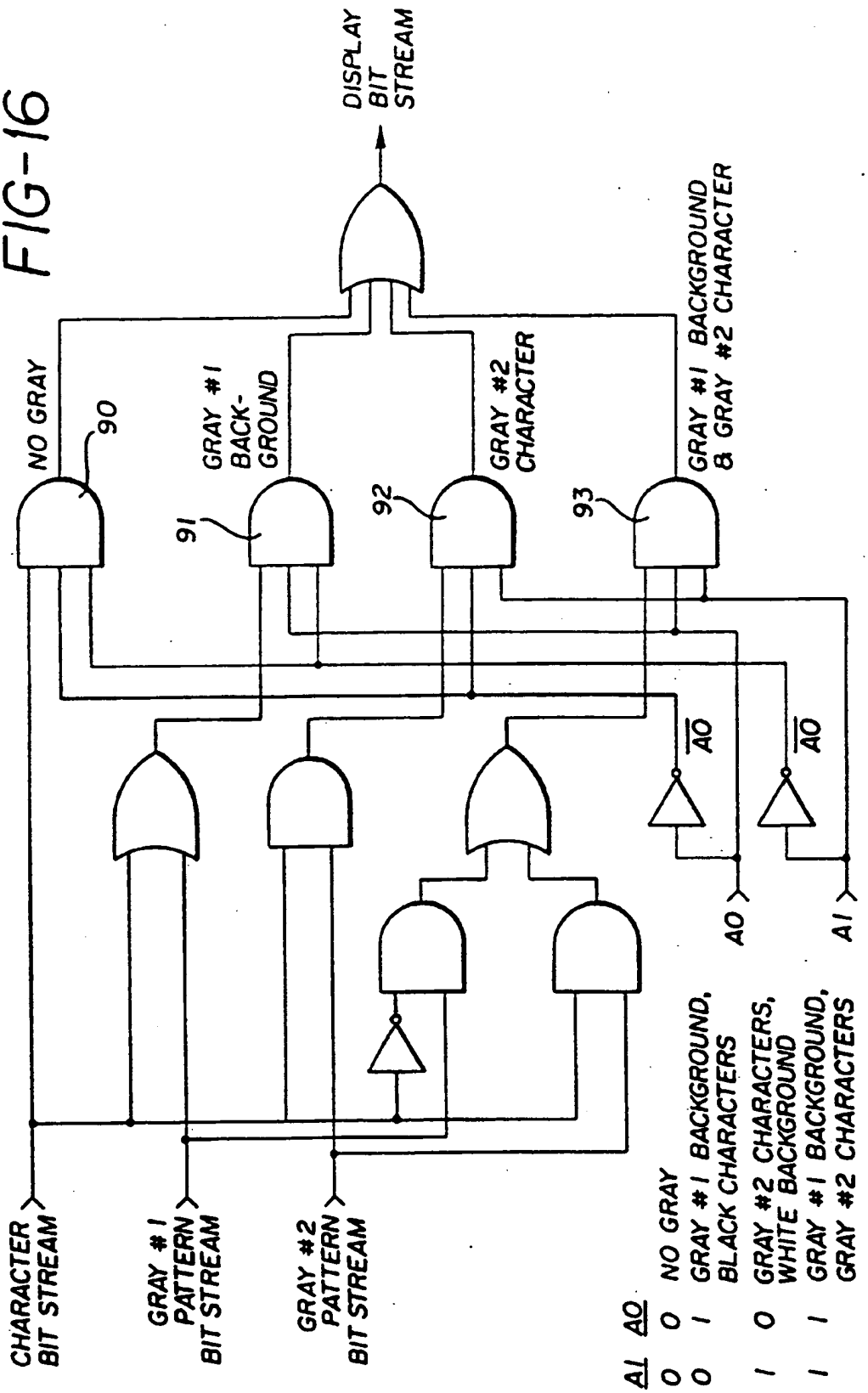


FIG-16


DISPLAY BIT STREAM
NO GRAY
90
GRAY #1 BACK-GROUND
91
GRAY #2 CHARACTER
92
GRAY #1 BACKGROUND & GRAY #2 CHARACTER
93
$\overline{A0}$
$\overline{A0}$
A0
A1
CHARACTER BIT STREAM
GRAY #1 PATTERN BIT STREAM
GRAY #2 PATTERN BIT STREAM
A1 A0
0 0 NO GRAY
0 1 GRAY #1 BACKGROUND, BLACK CHARACTERS
1 0 GRAY #2 CHARACTERS, WHITE BACKGROUND
1 1 GRAY #1 BACKGROUND, GRAY #2 CHARACTERS